AN EXPERIMENTAL LASER RANGING SYSTEM

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Summary

An experimental ranging system has been constructed utilizing the ruby laser of T.H. Maiman. When excited by a xenon flash tube the ruby laser emits a pulse of red light (6943Å) of high spectral purity. The beam emanating from the laser is already quite well collimated. With the addition of a telescope an extremely narrow beam of 0.4 milliradians is obtained. This light is reflected from a target and the return signal collected on a photomultiplier by means of another telescope. Spectral filtering provides discrimination against unwanted optical signals. Both transmitted and reflected signals are displayed on a dual beam oscilloscope and range is calculated from the displacement of the traces.

Ranging was successfully accomplished at 3000 meters in broad daylight and at 11,200 meters at night. Calculations have been made to establish limiting factors and to indicate ways of improving performance.

Introduction

Among the many potential applications of the solid state laser, a ranging system appears to be one of the most promising. In order to exploit the achievement of an operating laser[1,2] in this direction, an effort was undertaken to [illegible] an experimental ranging system (radar) utilizing a ruby laser, together with components and techniques which were readily available. In addition, the question has also been studied, what can be done with lasers and auxiliary components specifically developed and matched for this application? The purpose of this paper is to report on the achievement of a rudimentary ranging device with a minimum developmental effort and to indicate briefly the theoretical examination of the possibilities and limitations of more sophisticated and better designed systems. The first part of this paper is devoted to the description of the system as it was actually built and tested; this is then followed by a resume of the performance data and finally by discussions of theoretical and speculative nature concerning laser ranging systems to be built in the future.

Organization of the System

The transmitter of the laser ranging system is a ruby crystal with linear dimensions of the order of an inch. The ruby is driven by a pulse of white light from a xenon flash tube. The crystal itself acts as a highly directive radiator. Aiming of the beam is accomplished by orienting the crystal in the proper direction. When the natural collimation of the laser beam is inadequate, a lens system or telescope is added to decrease the beamwidth.

Light reflected from the target is gathered by a telescope and then detected by a photomultiplier tube, which converts the light into an electrical signal. This signal is then displayed on the screen of an oscilloscope which also displays a sample of the transmitted signal. Range is determined from the displacement of the received signal with respect to the transmitted one. A block diagram of the system is given in Fig. 1. In addition to the elements shown in Fig. 1, there is an optical filter incorporated in the telescope. The

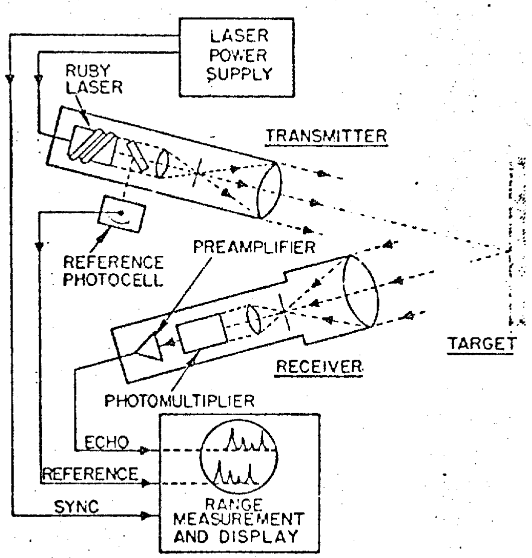

Fig. 1. Block diagram of system.

purpose of the filter is to provide discrimination against light not originating in the laser. This is essential in order to exploit one of the principal features of the laser, the concentration of energy in a very narrow spectral region.

The Components

The key element of the system is the ruby laser whose principal characteristics are tabulated below.

Laser Characteristics

Energy input per pulse	1200 joules
Peak optical power output	300-2000 watts
Frequency, f	4.321×10^{14} cps
Wavelength, λ	6943×10^{-8} cm
Wavelength band $\Delta\lambda$	$< 0.1 \times 10^{-8}$ cm
Width of radiated beam:	
Laser alone	12 milliradians (0.7°)
With telescope	0.4 milliradians (1.4')

Fig. 2 is a photograph of the laser which was constructed for this experiment by T. Maiman, who was responsible for the first operating ruby laser.[1] The crystal is surrounded by a xenon flash tube

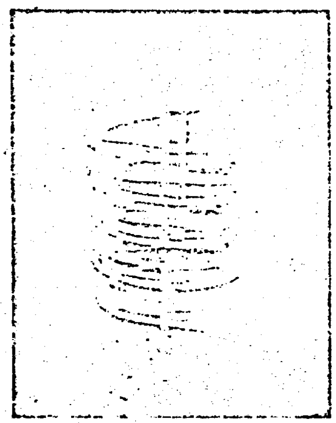

Fig. 2. Ruby laser.

capable of generating an intense flash of essentially white light. The flash is produced by discharging a capacitor bank of 2000 μf charged to about 1350 volts; it lasts about 1 msec. The emission of coherent radiation from the ruby begins a few hundred microseconds after the onset of the flash. The intensity of the emitted light is a very irregular function of time as shown in Fig. 3. Optical power output was measured with a diode-connected 6217 photomultiplier which had been calibrated by comparison, at 6943 Å, with a standard thermopile.

Ideal lasers should eventually provide extremely well collimated output beams (~10^{-5} radians). Because the beamwidth of the ruby laser used here is 12 milliradians, most of the experiments were conducted with a 6-inch reflecting telescope which provides an angular demagnification factor of 34. The 0.4 milliradian beamwidth

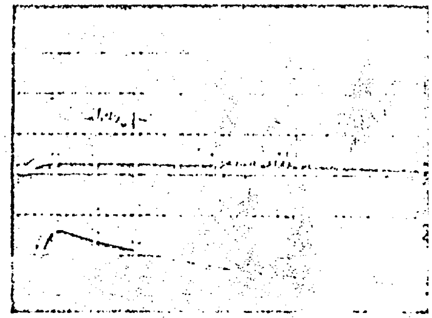

Fig. 3. Laser output. The upper trace gi[illegible] laser output intensity versus time; lower trace shows the output of th[illegible] pumping xenon flash lamp.

of the system was measured by observing th[illegible] diameter of the spot (7 ft) at 3.4 miles.

A time reference for range measurer[illegible] is established by sampling the laser output. [illegible] is accomplished by the use of a partially refl[illegible] glass plate and a photocell with red Wratten [illegible] neutral density filters.

Light is gathered in the receiver by a [illegible]atively large aperture telescope (5-inch diam[illegible] area of aperture = 0.0126 m^2, f/2.5). The [illegible] is filtered and then directed onto the cathode [illegible] the photomultiplier. In order to obtain good [illegible] crimination against noise, a narrow band opt[illegible] filter must be used. This requires an interf[illegible] filter which has certain peculiarities which [illegible] ence the design of the telescope optics. Interf[illegible] ence filters must be operated near normal in[illegible] dence; the rays must be nearly parallel at the [illegible] of the insertion of the filter. Moreover, the [illegible] able interference filters are relatively small [illegible] area. Finally, while their passband is narr[illegible] interference filters provide only about 30 db [illegible] crimination against unwanted radiation. It i[illegible] shown in Fig. 4 that a combination of two len[illegible] is used to reduce the cross section of the bea[illegible] light without changing the parallelism of the [illegible] and the interference filter is inserted in the [illegible] row beam. To enhance rejection of light in c[illegible] tain undesirable spectral regions beyond the [illegible] capability of the interference filter, a broad [illegible] Wratten filter is also inserted. It is placed [illegible] region where the rays are convergent becaus[illegible] angle of incidence is not critical in this case [illegible] field stop in the common focal plane of the tw[illegible] lenses serves to limit the solid angle from w[illegible] light is permitted to fall on the receiver. Th[illegible] adjustable from 1 to 20 milliradians; a beam [illegible] of 2.5 milliradians (5×10^{-6} steradians) was [illegible] quently employed.